will be used for all other nonmesothelial tumors with the magnitude of the increase in insulators being adjusted by the observed frequency of these tumors compared with that expected and that of other groups by their estimated exposure relative to insulators as well.

The treatment of the time course of mesothelioma differs from that of lung cancer and other malignancies in that there is no background rate in the absence of asbestos exposure with which to compare the asbestos-related risk. Thus, it is necessary to utilize absolute risks of death. Figure 4 shows the risk of death of mesothelioma according to age for individuals exposed first between ages 15 and 24 and between ages 25 and 34 as in Figure 1. As can be seen, these data, while somewhat uncertain because of small numbers, roughly parallel one another by ten years as did the increased relative risk curves for lung cancer. Thus, the absolute risk of death from mesothelioma appears to be directly related to onset of exposure and is independent of the age at which the exposure occurs. The risk of death from mesothelioma among the insulation workers is plotted according to time from onset of exposure on the right side of Figure 4. It increases as the fourth or fifth power of time from onset of exposure for about 40 or 50 years. Thereafter, data are scanty and information on the time course is not reliable. For the purposes of analyzing the mortality experience among various groups of workers, the relationship depicted in Figure 4 will be used. After 45 years from onset of exposure, we will consider the risk of death from mesothelioma to remain constant at 1.2 per 100 person-years for insulation workers employed for 25 or more years. For insulators employed for shorter periods, the risk will be reduced by the fraction of 25 years worked. For other exposed groups the risks depicted in Figure 4 will be reduced by the relative exposure of the group compared with insulators and by the fraction of 25 years that a population is exposed.

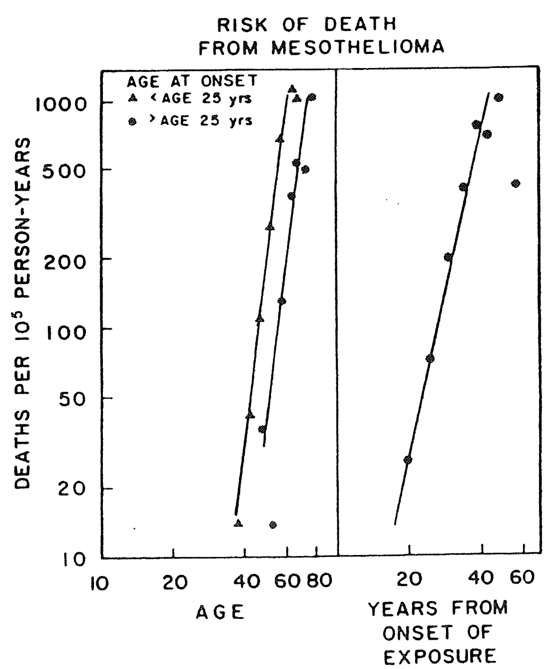

Fig. 4. The death rates for mesothelioma among insulation workmen according to age and age at onset of employment and according to time since onset of employment.

Dose-Response Relationships for Asbestos-Related Cancer

Four recent studies have demonstrated that the risk of lung cancer increases linearly with dose over a fairly wide range of exposures [Dement et al, in press; Henderson and Enterline, 1979; Liddell et al, 1977; Seidman et al, 1979]. Unfortunately, the studies are not directly comparable. For three, the measure of dose was the exposure to asbestos and other dusts in terms of millions of particles per cubic foot (mppcf) times the duration of exposure. This exposure categorization is highly dependent upon the proportion of nonfibrous material in the aerosol being considered. Some relationships between particle counts and fiber concentrations in fibers longer than 5 micrometers per milliliter (f/ml) have been provided in the literature, but these are tenuous at best, based as they are upon a limited number of observations. Further, the study of Henderson and Enterline [1979] was limited to retirees over age 64 of a major asbestos products manufacturer in the United States. As was seen in Figure 2, observations of exposed groups begun late in life can differ considerably from those in which follow-up starts at younger years (as, for example, at age 40–45, 20 years after onset of employment). In the fourth study, that of Seidman et al [1979], exposure characterization involved the use of data from plants other than that in which the mortality experience occurred. A discussion of some of the differences of the slopes of the dose-response functions obtained in these studies has been made elsewhere [Nicholson, 1981a]. The important aspect is the linearity of effect with increasing amounts of asbestos inhaled.

In the analysis which follows, it is not necessary that one fully understand the reasons for the differences in the slopes of dose-response relationships in mining and various manufacturing operations as the relative risks in different industries will be based largely upon the observed mortality experience in those industries or upon a comparison of the number of cases of mesothelioma or excess lung cancers in different work activities. In this subsequent comparison, however, we will utilize a linear dose-response relationship to adjust for different periods of employment. While the evidence of linearity is strong for lung cancer, we will assume that it also obtains for mesothelioma and other malignancies. The evidence for this is more limited, but an analysis of the risks of mesothelioma according to time of employment in the study of Seidman et al would suggest that it is true for that tumor as well. For example, 0 of 215 deaths from mesothelioma occurred from less than 6 months exposure, 3 of 82 from 6 to 11 months exposure, 4 of 74 from 1 to 2 years exposure, and 7 of 63 from more than 2 years exposure.

Calculation of Asbestos-Related Mortality

As discussed previously, for those trades in which workers have possible asbestos exposure, estimates were made of the number of employees potentially at risk, the relative exposure of those workers compared with insulators, the average employment time of individuals entering a particular trade or industry, and the age distribution of new hires in the various trades or industries. The asbestos-related cancer mortality was calculated as follows. For those employees entering a trade subsequent to 1940, the above data from Table XII were utilized to obtain the number of new entrants into an industry during different periods of time. The age distribution of new manufacturing employees of 1960 (Table XXI) was used to calculate age-related mortality of new entrants into a trade or industry. This distribution also was found in new hires during 1974 at a major northeast US shipyard (E. Christian, personal communication). For each quinquennium at entry, the appropriate age, calendar year, and asbestos risk specific rates were applied to calculate the excess lung and other cancer mortality, the risk

of death from mesothelioma, the total mortality (based on US national rates for the entry quinquennium and all subsequent quenquennia until the year 2030 (assuming 1975–1979 rates to apply to the year 2030). This was done for each five-year period of entry, 1940–1980, and the calculated numbers summed for each calendar quinquennium, 1940–2030. For those employed in 1940, the appropriate age distribution for an industry or trade in 1940, as given by the US census, was used. For those employed in 1940, it was assumed that onset of asbestos exposure occurred at age 22.5 or 1930 for those 32.5 years or older in 1940.

The excess, nonmesothelial cancer mortality was calculated using the time dependence displayed in Figure 2 with the assumption that the manifestation of risk from a given exposure will first take place 7.5 years after its occurrence and increases linearly until 7.5 years after cessation of exposure. The risks of death from mesothelioma were calculated using the data of Figure 4, adjusted for each industrial group, with risk assumed to be constant after 45 years from first exposure. Account was taken of the different periods of exposure for each group in each decade, as indicated in Table XIII. Calculations were made using US white male rates. Some blacks and some women would have been employed in the industries under consideration, although their numbers would have been small. Were data available on the number of blacks and women, the use of black male rates would have increased the number of nonmesothelioma cancers and the female rates would have decreased the number, resulting in only a small change from these data.

The results of such calculations are shown in Table XXII through XXV, which list the average annual excess number of lung cancers, mesotheliomas, gastrointestinal, and other asbestos-related cancers, and total excess cancer attributable to asbestos exposure in each quinquennium from 1965 to 2030 for the populations in Table XII. In these tables the average annual mortality in each quinquennium is listed by the midyear of the period. As can be seen, the dominant contributors to the asbestos-related disease are the shipbuilding and construction industries. Industries directly involved in the manufacturing of asbestos products or with the application of insulation material contribute a significantly smaller proportion to current asbestos disease and that to be expected for the next two decades.[2]

It is instructive to look at a display of the number of mesotheliomas and asbestos-related cancers in the shipbuilding industry from the year 1940 to the year 2000. While the total number of malignancies are necessarily uncertain, the data on the time course of the cancers that will occur are relatively good. These data are shown in Figures 5 and 6 for the populations first employed prior to 1940, during World War II, and subsequent to 1945. As can be seen, the relative importance of the wartime and postwar exposures are roughly equal, even though a considerably greater number of individuals were employed in World War II. This, of course, occurs because of the relatively short periods of work for the wartime group. Further, while the exposures in the construction industry are more uncertain, the important disease experience is also ahead of us in

[2]A preliminary report on this research has been presented elsewhere (W.J. Nicholson, G. Perkel, I.J. Selikoff, and H. Seidman. Cancer from occupational asbestos exposure: Projections 1980–2000. Banbury Report 9, Cold Spring Harbor Laboratory, 1981, pp 87–111). In that publication, an estimate was presented of the population at risk from asbestos exposure since 1940 (13,200,000) and projections of asbestos-related mortality (8,770 deaths in 1982 to 9,750 in 1990). The estimates of the population exposed to asbestos presented there, however, did not fully account for the extremely high turnover in workplace employment that we have discussed here. However, as the mortality estimates did not depend on the total population exposed, they are virtually identical to those presented here.

that industry, largely because of the extensive use of asbestos in spray fireproofing materials between 1958 and 1972. A measure of the overall future disease experience can be seen in Figure 7, which depicts the projected annual mesothelioma deaths from 1940 to the year 2000. Of all mesotheliomas that are estimated to occur between the years 1940 and 2000, about one third have occurred to date.

The number of mesotheliomas estimated by this procedure is approximately 40% greater than those that would be estimated to occur nationwide using data of the SEER program for white males during 1978 [R. Connelly, National Cancer Institute, personal communication, 1981]. Here, initial data (with one center not analyzed) report 98 mesothelioma deaths in nine of the ten SEER areas. As they represent approximately a

TABLE XXI. Age Distribution of Employees Hired During 1965 Who Were Not Working January 1, 1965*

Age	Number (in thousands)	Percent in age interval	Percent of shipyard workers in age interval[a]
18–19	892	15.1	17.8
20–24	1,614	27.3	31.6
25–34	1,431	24.3	27.6
35–44	861	14.6	12.0
45–54	588	10.0	6.1
55–64	361	6.1	2.9
65 +	146	2.5	0.0

*Data from Bureau of Labor Statistics [1965].
[a]Based on 478 new hires during 1974. Data from Christian, Sec. Local 5, Industrial Union of Marine and Shipbuilding Workers of America (personal communication, 1981).

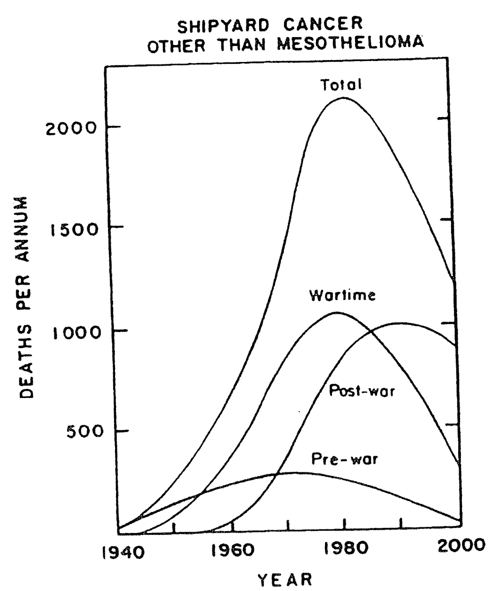

Fig. 5. The estimated and projected numbers of mesothelioma deaths per annum from past asbestos exposure from 1940 through 1999 among three groups of shipyard employees (those employed in 1940 or earlier, those employed during World War II, and those employed subsequent to World War II).

10% sample of the US population, the national estimate of cases for 1978 would exceed 1,000. This is to be compared with our estimate of 1,400 for the quinquennium 1976–1980 (and for the year 1978). In this comparison, however, it should be noted that the information used for the estimate of asbestos-related cancers in this work relied upon data that identified asbestos malignancy following analysis of all medical evidence and after a review of all pathological material available. The SEER program, on the other hand, used records-based reports with no review of pathological material. Experience has shown that pathological review will identify as mesothelioma many neoplasms initially categorized otherwise [Levine, 1978]. Further, while well representing the shipbuilding industry, the ten SEER areas underrepresent industrial areas and

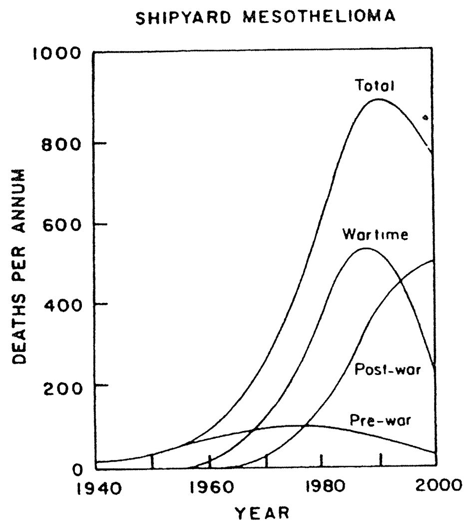

Fig. 6. The estimated and projected numbers of excess asbestos-related cancers per annum from 1940 through 1999 among three groups of shipyard employees (those employed in 1940 or earlier, those employed during World War II, and those employed subsequent to World War II).

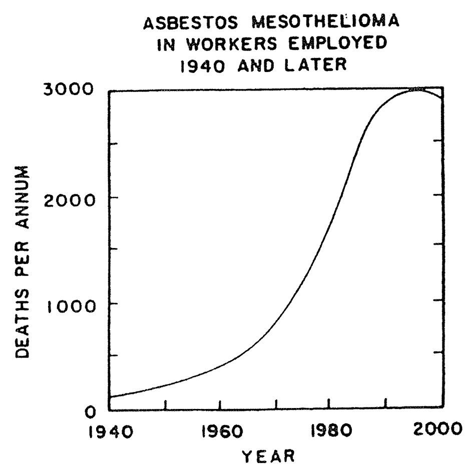

Fig. 7. The estimated and projected numbers of mesotheliomas per annum from 1940 through 1999 from occupational asbestos exposure.

TABLE XXII. The Projected Annual Excess Deaths From All Asbestos-Related Lung Cancer in Selected Occupations and Industries, 1967–2027

	Number deceased in calendar year												
Industry or occupation	1967	1972	1977	1982	1987	1992	1997	2002	2007	2012	2017	2022	2027
Primary asbestos manufacturing	129	189	240	270	288	284	260	224	173	122	77	43	20
Secondary manufacturing	146	192	261	321	374	387	377	343	291	228	160	102	56
Insulation work	158	235	319	379	418	421	390	333	299	185	119	68	35
Shipbuilding and repair	847	1,125	1,411	1,479	1,436	1,247	1,027	786	562	401	268	157	78
Construction trades	445	717	1,093	1,405	1,649	1,815	1,893	1,828	1,584	1,235	884	487	228
Railroad engine repair	66	79	88	84	62	55	36	19	8	2	0	0	0
Utility services	82	111	142	161	175	177	168	150	124	95	66	41	22
Stationary engineers and firemen	234	306	380	435	478	493	486	438	378	305	223	147	85
Chemical plant and refinery maintenance	116	163	209	246	267	270	254	224	181	136	93	56	30
Automobile maintenance	100	142	192	240	290	316	340	326	304	266	210	148	90
Marine engine room personnel	21	27	33	35	35	32	28	22	17	12	8	5	2
Totals	2,344	3,286	4,368	5,055	5,472	5,497	5,259	4,693	3,921	2,987	2,108	1,254	646

metropolitan regions that would have had significant construction activities 30 or more years ago. Thus, it is not unexpected that actual US rates may exceed those estimated from the SEER program.

There is observational evidence to support the analytical approach used in these calculations. The data for insulation workers suggest that 650 mesotheliomas and 2,300 excess lung cancers would occur between 1967 and 1976 among members of this craft. This is to be compared with 175 mesotheliomas and 380 excess lung cancers seen among insulators in the single union (The International Association of Heat and Frost Insulators and Asbestos Workers, AFL-CIO) studied by Selikoff et al [1979]. The ratios of 0.27 and 0.17 for the number of deaths among Asbestos Workers Union members to those calculated here is in reasonable agreement with the fraction of all insulators that the union has organized (0.29). The difference in lung cancer and mesothelioma ratios can be attributed to the fact that the insulators organized by this union are older than the entire group estimated to be at risk from 1967 through 1976 and, thus, have a proportionally greater risk of death from mesothelioma than from lung cancer compared to other insulators. Forty-two percent of the Asbestos Workers Union members were 45 years of age or older at the midpoint of the Selikoff et al study. A comparison of the ratios of the calculated 1977 mesothelioma deaths from industries (Table XXIII) with those observed in the study of McDonald and McDonald [1980] (Table XVI) also shows reasonable agreement.

As discussed previously, one third of those estimated to have had a potential exposure to asbestos were exposed for only a short period of time and were believed to have a risk less than that equivalent to that from employment in an asbestos products plant or as an insulator for two months. By calculating the person-years of exposure of the "lower risk population" and comparing the result to the total person-years of employment in each industry the contribution of the lower-risk group to the estimated excess mortality can be obtained. These results are shown in Table XXVI and indicate that 32% of the exposed group will contribute less than 2% of the excess asbestos-related deaths. The numbers are approximate because of uncertainties in the assumed short-term separating rate. They do, however, dramatize the consequences of inclusion of lower exposed individuals in the population at risk.

Asbestosis Deaths

The above estimates are of deaths from malignancy. There will be additional deaths from asbestosis that will occur in individuals exposed to high concentrations over long periods of time. In contrast to the asbestos cancers, deaths from asbestosis generally require considerable fiber exposure. They will largely occur in insulators, manufacturing workers and long-term shipyard employees. They will be fewer than the number of mesothelioma deaths among insulators (perhaps one half to three fourths). Because of the high labor turnover in manufacturing we would estimate that about one third as many deaths will occur from asbestosis as from mesothelioma. A similar ratio is probably appropriate for pre- and post-World War II shipyard workers (short-term wartime work would carry only a limited risk of death from asbestosis). Thus, approximately 200 deaths annually are now occurring from asbestosis (the condition, however, will be contributory to many more deaths). This number will perhaps double during the next two decades and decline thereafter.

TABLE XXIII. The Projected Annual Deaths From Asbestos-Related Mesothelioma in Selected Occupations and Industries, 1967–2027

Industry or occupation	Number deceased in calendar year												
	1967	1972	1977	1982	1987	1992	1997	2002	2007	2012	2017	2022	2027
Primary asbestos manufacturing	56	64	80	102	128	149	160	161	147	123	89	59	34
Secondary manufacturing	42	52	70	99	134	167	195	213	214	199	163	123	78
Insulation work	51	65	91	130	173	207	227	229	209	157	128	86	50
Shipbuilding and repair	292	386	542	612	884	865	770	659	541	409	287	201	120
Construction trades	169	193	251	355	495	696	901	1,065	1,176	1,126	882	624	378
Railroad engine repair	38	42	50	60	65	60	45	30	18	7	2	0	0
Utility services	37	41	49	62	76	87	96	99	96	86	68	50	31
Stationary engineers and firemen	120	125	148	168	207	238	259	262	247	214	165	117	71
Chemical plant and refinery maintenance	46	55	70	91	117	138	149	152	145	128	99	71	44
Automobile maintenance	40	48	60	78	100	122	148	172	190	200	190	158	108
Marine engine room personnel	10	11	14	18	19	19	19	18	16	12	9	6	3
Totals	901	1,082	1,425	1,775	2,398	2,748	2,969	3,060	2,999	2,661	2,082	1,495	917

Comparison With Other Studies

Some previous estimates of asbestos-related mortality exceed those discussed here. In the Department of Health, Education, and Welfare estimate that 13%–18% of all cancers in the near future will be asbestos-related, recognition was taken that a large number of individuals were potentially exposed to asbestos, their estimate being 8–11 million compared with ours at 27.5 million, 18.8 million of whom had exposures greater than 2–3 f-yr/ml [Department of Health, Education, and Welfare, 1981]. However, their estimates of the number of heavily exposed individuals was subjective and no explicit adjustment was made for the different employment periods of exposed groups. The estimates by Hogan and Hoel [1981] that up to 12,000 deaths may occur annually from asbestos cancer placed great emphasis upon possible effects from the shipbuilding industry. They, too, subjectively estimated the number of heavily exposed individuals in this trade and did not explicitly account for variations in employment time and may have overestimated the asbestos-related mortality. However, their estimates of the effect of other industries neglected large numbers of individuals with potential exposure. Thus, their estimates for other than shipbuilding would appear to understate the asbestos disease potential [Nicholson, 1981b]. Finally, Blot and Fraumeni [1981] estimate that 120,000 lung cancer deaths will occur (over the population lifetime) from wartime shipyard employment. Our estimate is 25,000. The difference lies largely in our assigning a much lower risk to the very short term (< 1 year) employees.

A lower estimate of 4,000 asbestos cancers annually has been made by Higginson et al [1980] based upon mid-1970 SEER data for mesothelioma and a multiplier of three for other cancers. However, the multiplier depends on time from onset of exposure and population age and exceeded four during the 1970s. (Compare Tables XXII and XXIII.) Further, the previously mentioned limitations of the SEER data apply here. Enterline has also estimated that approximately 4,000 deaths will occur annually [Enterline, 1981]. He attributes 530 lung cancer deaths/yr to primary manufacturing and insulation work, 900 to secondary, 421 to shipyard employment, 212 to auto maintenance, and 438 for other occupations. In addition to lung cancer, he estimates 1,250 other cancers and 333 mesotheliomas will be asbestos-related. The values for primary manufacturing, insulation work, and auto maintenance are similar to our estimates and that for secondary manufacturing considerably more. However, much lower estimates are given for shipbuilding, construction, and other trades. This is in contrast with the finding that a much greater number of mesotheliomas occur in these trades compared with manufacturing and insulation work [McDonald and McDonald, 1980].

Expected Mortality in Asbestos-Exposed Workers

Tables XXII through XXV list the projections for the excess mortality associated with past asbestos exposures. For a given work category, these excess deaths will add to those expected in the absence of exposure but, with the exception of mesothelioma, an "excess" death cannot be distinguished from an "expected" one. As each of these deaths may lead to a claim for compensation or a third party suit, the potential of such cases can greatly exceed the number of excess deaths calculated above. For the heavily exposed (insulators, for example), where the excess deaths exceed those expected, the problem is not a great one. However, for groups with lesser exposure, the total number of lung cancer deaths that could be asbestos-related is very much greater than the numbers in Table XXII. Table XXVII lists the expected lung cancer deaths over the

TABLE XXIV. The Projected Annual Excess Deaths From All Asbestos-Related Gastrointestinal and Other Cancers in Selected Occupations and Industries, 1967–2027

Industry or occupation	Number deceased in calendar year												
	1967	1972	1977	1982	1987	1992	1997	2002	2007	2012	2017	2022	2027
Primary asbestos manufacturing	52	59	65	73	78	77	71	60	47	33	21	12	6
Secondary manufacturing	48	60	72	87	102	105	102	93	79	62	44	27	15
Insulation work	57	74	87	103	114	114	106	90	70	50	32	19	9
Shipbuilding and repair	313	354	384	402	390	339	279	214	153	109	73	43	21
Construction trades	164	225	297	383	449	493	514	497	431	336	230	132	63
Railroad engine repair	25	25	24	23	20	15	10	5	2	1	0	0	0
Utility services	30	35	39	44	48	48	46	41	34	26	18	11	6
Stationary engineers and firemen	80	96	103	118	131	134	130	119	103	83	61	40	23
Chemical plant and refinery maintenance	43	51	58	67	73	74	69	61	49	37	25	15	8
Automobile maintenance	36	46	52	66	80	86	90	88	82	72	58	40	24
Marine engine room personnel	8	9	9	10	10	9	8	6	5	3	2	1	1
Totals	856	1,034	1,190	1,376	1,495	1,494	1,425	1,274	1,055	812	564	340	176

TABLE XXV. The Projected Annual Excess Deaths From All Asbestos-Related Cancer in Selected Occupations and Industries, 1967–2027

Industry or occupation	Number deceased in calendar year												
	1967	1972	1977	1982	1987	1992	1997	2002	2007	2012	2017	2022	2027
Primary asbestos manufacturing	237	312	385	445	494	510	491	445	367	278	187	114	60
Secondary manufacturing	236	304	403	507	610	659	674	649	584	489	367	252	149
Insulation work	266	374	497	612	705	742	723	652	578	392	279	173	94
Shipbuilding and repair	1,452	1,865	2,337	2,493	2,710	2,451	1,076	1,659	1,256	919	628	401	219
Construction trades	778	1,135	1,641	2,143	2,593	3,004	3,308	3,390	3,191	2,697	1,996	1,243	669
Railroad engine repair	129	146	162	167	147	130	91	54	28	10	2	0	0
Utility services	149	187	230	267	299	312	310	290	254	207	152	102	59
Stationary engineers and firemen	434	527	631	721	816	865	875	819	728	602	449	304	179
Chemical plant and refinery maintenance	205	269	337	404	457	482	472	437	375	301	217	142	82
Automobile maintenance	176	236	304	384	470	524	578	586	576	538	458	346	222
Marine engine room personnel	39	47	56	63	64	60	55	46	38	27	19	12	6
Totals	4,101	5,402	6,983	8,206	9,365	9,739	9,653	9,027	7,975	6,460	4,754	3,089	1,739

years 1965–2030 (assuming 1978 rates for subsequent years). As can be seen, the expected numbers exceed the excess by nearly six times. Even if the 32% of individuals with lower exposure are excluded from consideration, the ratios of expected to excess range from 0.4 to 11.7.

Figure 8 shows the distribution of excess lung cancers expected between 1980 and 2030 according to equivalent insulator-years of exposure. (An insulator-year of exposure is that which would create the same risk as employment as an insulator for one year). The approximate exposure for a doubling of lung cancer risk is also indicated. Of the excess lung cancers, 50% occur in individuals with more than this doubling exposure. The total number of lung cancers is also shown for this group and is about 60% more than the excess due to asbestos exposure. For lesser exposures, the curve of the total cancer rises extremely steeply because of the large number of exposed individuals. At the peak of the asbestos related lung cancer curve, the total lung cancer curve would be four times higher. Parenthetically, the exposure distribution of mesothelioma cases will be similar to that of the excess lung cancers.

As mentioned previously at a given exposure level an "excess" death cannot be distinguished from an "expected" one. The problem, however, extends even across exposure levels. Many individuals with less than 5 insulator-years of exposure will have abnormal X-rays, and a significant percentage with greater exposure will have normal X-rays. This follows from the finding that more than 30% family contacts of

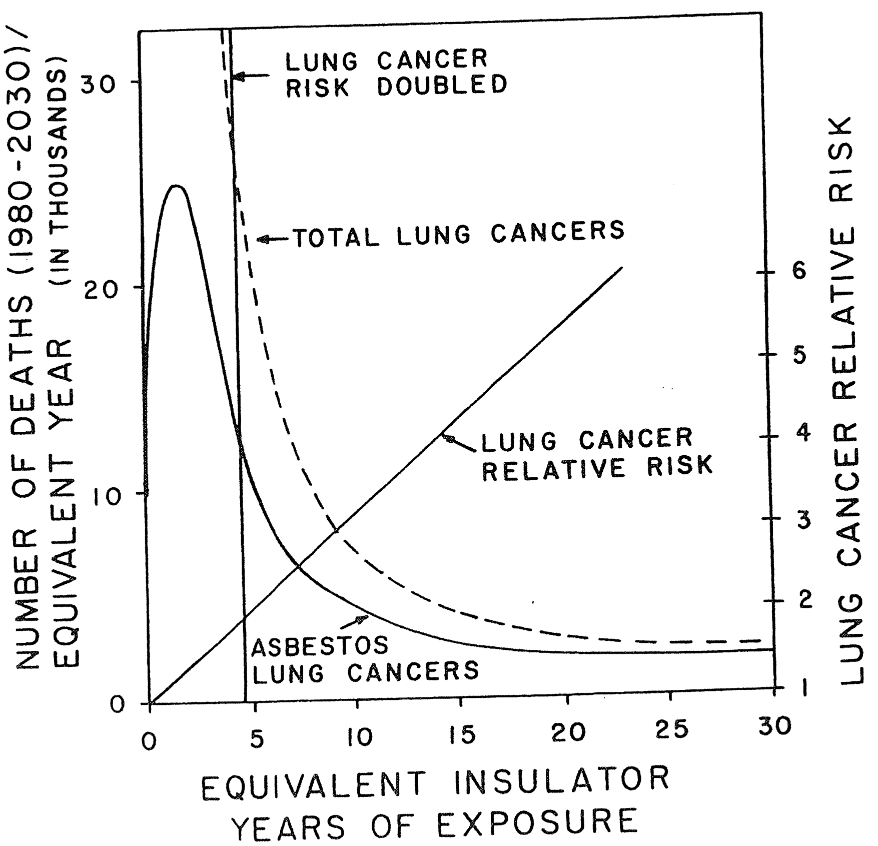

Fig. 8. The distribution of excess lung cancers expected between 1980 and 2030 according to equivalent insulator-years of exposure. (An insulator-year of exposure is that which would create the same risk as employment as an insulator for one year.)

TABLE XXVI. Percentage of Asbestos-Related Cancers That Occur Among Those With Lower Exposure Who Were Exposed After January 1940*

Industry or occupation	Percentage of deaths
Primary asbestos manufacturing	1.2
Secondary manufacturing	1.3
Insulation work	0.1
Shipbuilding and repair	1.9
Construction trades	1.0
Railroad engine repair	1.8
Utility services	0.8
Stationary engineers and firemen	1.8
Chemical plant and refinery maintenance	1.0
Automobile maintenance	12.4
Marine engine room personnel	2.3

*Lower exposure is considered to be less than 2–3 f-yr/ml. The overall contribution to mortality of all individuals with lower exposure is 1.9%.

asbestos factory workers (Anderson et al, 1979) and insulators (Nicholson et al, to be published) have asbestos related X-ray abnormalities (20-30 years after onset of less than 5 equivalent years of exposure) and that a fair number of insulators with 20 or more years in the trade have normal X-rays. Pulmonary function tests are even less revealing. While procedures based on exposure or on clinical evidence of exposure are possible, the allocation of compensation resources to the deserving individuals is clearly an enormously difficult scientific problem. It is an even more difficult social problem.

CONCLUSIONS

Estimates have been made of the numbers of cancers that are projected to result from past exposures to asbestos in a number of occupations and industries. Only those potentially exposed by virtue of their employment have been considered. Additional deaths will result from exposure among family contacts (household contamination), from environmental exposures, from exposure during consumer use of asbestos products, and from exposure while in the Armed Forces, particularly in engine rooms of naval ships. No estimates have been made of deaths resulting from asbestosis. These estimates indicate that:

1. From 1940 through 1979, 27,500,000 individuals had potential asbestos exposure at work. Of these, 18,800,000 had exposure in excess of that equivalent to two months employment in primary manufacturing or as an insulator (>2–3 f-yr/ml). 21,000,000 of the 27,500,000 and 14,100,000 of the 18,800,000 are estimated to have been alive on January 1, 1980.
2. Approximately 8,200 asbestos-related cancer deaths are currently occurring annually. This will rise to about 9,700 annually by the year 2000.
3. Thereafter, the mortality rate from past exposure will decrease but still remain substantial for another three decades.

TABLE XXVII. Expected Lung Cancer Deaths in Selected Occupations and Industries, 1967–2027

Industry or occupation	Number deceased in calendar year												
	1967	1972	1977	1982	1987	1992	1997	2002	2007	2012	2017	2022	2027
Primary asbestos manufacturing	230	327	435	528	604	646	642	588	499	400	308	238	186
Secondary manufacturing	424	628	870	1,100	1,297	1,446	1,518	1,497	1,394	1,237	1,047	833	605
Insulation work	67	97	132	162	187	204	210	203	187	164	138	109	79
Shipbuilding and repair	4,420	5,956	7,550	8,694	9,202	8,553	7,541	5,522	3,595	2,188	1,478	1,144	800
Construction trades	2,501	3,793	5,325	6,761	8,033	9,061	9,648	9,677	9,173	8,246	7,005	5,536	3,942
Railroad engine repair	258	334	404	441	451	421	350	248	143	62	17	20	0
Utility services	316	438	572	684	770	819	827	764	672	566	461	358	256
Stationary engineers and firemen	1,703	2,316	2,969	3,491	3,895	4,114	4,080	3,769	3,253	2,660	2,082	1,557	1,075
Chemical plant and refinery maintenance	736	1,026	1,139	1,576	1,791	1,881	1,870	1,715	1,474	1,205	948	716	504
Automobile maintenance	2,761	3,969	5,358	6,592	7,572	8,231	8,450	8,172	7,543	6,894	5,731	4,646	3,436
Marine engine room personnel	177	236	295	337	361	363	338	288	231	176	133	97	64
Totals	13,593	19,120	25,049	30,366	34,136	35,739	35,374	32,443	28,164	23,798	19,398	15,236	10,947

These projections are from past exposures to asbestos. Over one million tons of *friable* asbestos material are in place in buildings, ships, factories, refineries, power plants, and other facilities. The maintenance, repair and eventual demolition of these facilities provide opportunities for continued significant exposures. If such work is not properly done, or if asbestos is otherwise used with inadequate controls, the burden of disease and death from past exposures will be increased by the environmental exposures of the future.

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